iCub Robot Gets Battery Power with Help of Tektronix Oscilloscope, Voltage and Current Probes

Customer Solution Summary

December 2014

Challenge

Developers at the Istituto Italiano Di Tecnologia (IIT) needed to validate and troubleshoot a new battery backpack power supply system for the iCub robot, an open-source cognitive humanoid robot platform about the size of a four-year-old child.

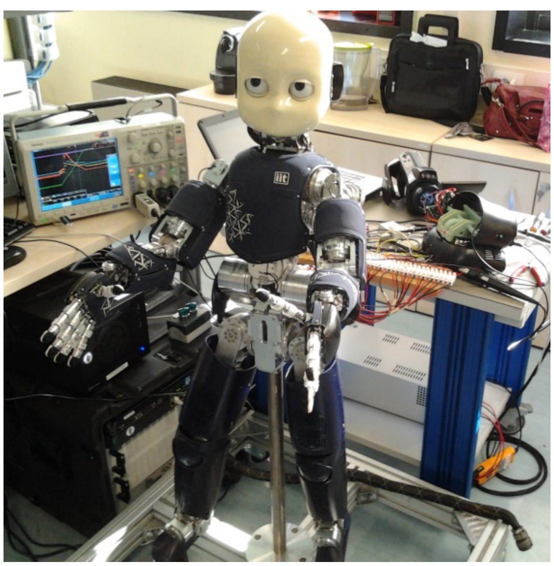
Solution

To complete the project, IIT turned to a Tektronix MSO4104B oscilloscope with a TDP1000 differential probe, TCP0030 current probe and four TPP1000 probes along with decoder modules to measure analog signals, power characteristics and bus communications.

Benefits

Using the Tektronix oscilloscope, IIT engineers were able to efficiently isolate problems, manage power spikes during start-up and characterize battery discharge. The ability to decode data streams proved vital to validating the CAN and I2C data across the three circuit boards used in the backpack's design.

iit iCub ISTITUTO ITALIANO DI TECNOLOGIA
iCUB FACILITY



A Tektronix MSO4104B oscilloscope was used in the development of the iCub robot's battery backpack.

Open Source Robot Platform

With the help of a Tektronix oscilloscope, you can now tell your iCub robot to stop bugging you and go outside to play. That's because instead of needing a long-extension cord for power, the iCub robot now has a battery backpack – tested and optimized using a Tektronix oscilloscope and power probes – to keep the sensors on, the circuits powered up and motors turning.

The iCub is a humanoid robot developed at Istituto Italiano Di Tecnologia (IIT, www.iit.it). Available as an open system platform under a GPL license, iCub has been adopted by more than 30 research institutions worldwide.

About the size of a 4-year-old child, iCub has 53 motors that move the head, arms and hands, waist, and legs allowing it to crawl on all fours and sit up and balance. It can see and hear, has the sense of proprioception (body configuration) and movement (using accelerometers and gyroscopes) and it is the first robot with an artificial skin covering its whole body.

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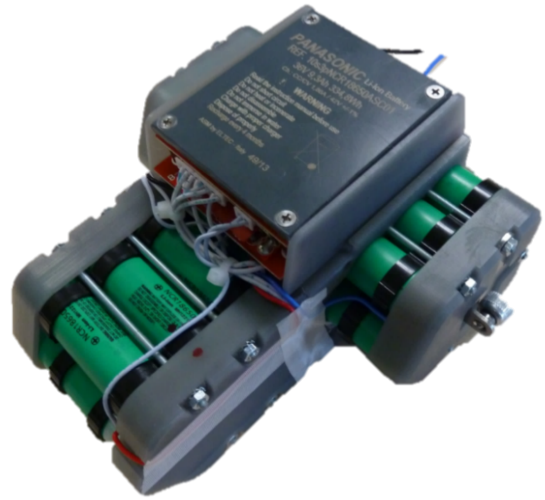
Advanced Power Solution Adds Mobility to iCub Platform



The new battery backpack contains a 36V-9.3Ah Li-On power source, enough to power the iCub for several hours of operation.

What the platform lacked, however, was the ability to go to places external to the lab environment without some sort of external power source and power cable. To address this limitation, IIT engineers have now developed a battery backpack that provides power to the robot. The design consists of:

- Li-Ion battery pack, 36V-9.3Ah.
- Battery Management System (BMS) board for keeping track of charge, overvoltage, overcurrent protection and cells balancing.
- Monitor board (BMON) for checking battery status including voltage, current and charge percentages.
- Power board to implement the DC/DC conversions from battery voltage to the iCub power supply and a Hot Swap Manager (HSM). The robot has 2 DC voltage levels: 12V 10A for the DC motors and the PC; and 36V 8A for the 26 brushless DC motors.
- Master board with a Bluetooth interface (BCB) to manage the whole system.

Verifying Power Management

Following the implementation of the basic battery backpack design, IIT's designers faced a number of test and measurement challenges to verify power management, set limits in order to stay with the safe operating ranges of the MOSFETs, determine power consumption, and validate data communications across the CAN and I2C buses used on the control boards.

The team's solution included a Tektronix MSO4104B oscilloscope with a TDP1000 differential probe, TCP0030 current probe, four TPP1000 probes and DPO 4AUTO and DPO4EMBD data decoder modules. This solution was used to measure the analog signals, power characteristics and bus communications of the electronic boards.

The MSO4104B oscilloscope features 1 GHz bandwidth with a sample rate of 5 GS/s. It supports up to 4 analog channels and 16 digital channels. Since the digital channels are fully integrated into the oscilloscope, users can trigger across all input channels, automatically time correlating all analog, digital, and serial signals.

With the addition of the appropriate power probes – from the wide cross-selection offered by the Tektronix – the MSO4000 series oscilloscopes are well-suited to power test applications such as the iCub battery backpack. For instance, the TCP0030 used by IIT is a high-performance, easy-to-use AC/DC current probe that provides greater than 120 MHz bandwidth with selectable 5 A and 30 A measurement ranges. It also provides low-current measurement capability and accuracy to levels as low as 1 mA.

> *"The oscilloscope made it very easy for us to adjust parameters correctly to ensure maximum protection for the MOSFETs."*
>
> Marco Maggiali, iCub development team

On Target Measurements

For measuring the outputs of the DC/DC converters and the HSM board, the voltage probe and the current probe were both used. Due to the high current flowing in the robot, the IIT team performed a number of different tests during start-up and normal operation. The screen capture below shows current, voltage and power levels during start-up of the Hot Swap Manager (HSM) board.

The analysis of the start-up transient (see Figure 1) proved necessary in order to tune the behavior of the HSM to stay beneath the power limits of the MOSFET transistors on the board, according to Marco Maggiali and Andrea Mura of the iCub development team. “Without actually performing analysis on the board, it’s very hard to know how it will perform in the real world,” says Maggiali. “The oscilloscope made it very easy for us to adjust parameters correctly to ensure maximum protection for the MOSFETs.”

Another challenge the team faced was the fact that robots are an inherently noisy environment with many different motors starting and stopping constantly. In this case, the TDP1000 differential probe was used for measuring the drop voltage on shunt resistors of the DC/DC converter and to evaluate noise levels in the output signal. This helped to direct the placement of choke filters, ground loops and shielding to minimize noise.

The oscilloscope also proved useful in evaluating battery life under a variety of conditions. Interestingly, it proved difficult to exercise the robot to its fullest where all 53 motors were running simultaneously, and in fact the team was not able to produce a truly worst case scenario. Like humans, rarely are all the possible combinations that go into creating movement used at the same time. After getting the robot as close to full movement as possible, the MSO4104B’s long 20M point record length was used to characterize battery discharge as shown in Figure 2. Under near worst-case scenarios, battery life came out to about 1.5 hours but would typically be much longer under more normal operation.

With three boards and two bus technologies, an important challenge confronting the team was to validate and debug data communications – a tedious task if performed manually. That’s where the DPO 4AUTO and DPO4EMBD data decoder modules made it easy to read and validate the data communications between the BCB (master board), HSM and the BMON (monitor board). The HSM communicates with the BCB through a 1 Mb/s CAN bus and the BMON connects through I^2C to the BCB. The BCB includes a Bluetooth interface to communicate battery status to a mobile device or the robot head. An example of the CAN and I^2C communication signals and the respective bytes decoded is shown in Figure 3.

Development of the iCub platform continues steadily at IIT with iCub 2.0 (including battery backpack) now in the works. While the iCub isn’t quite ready to go outside and play on its own, the robot continues to expand it repertoire of capabilities. To learn more about the impressive breakthroughs being enabled by the iCub platform – or to even obtain one for your own research efforts – visit http://www.icub.org.

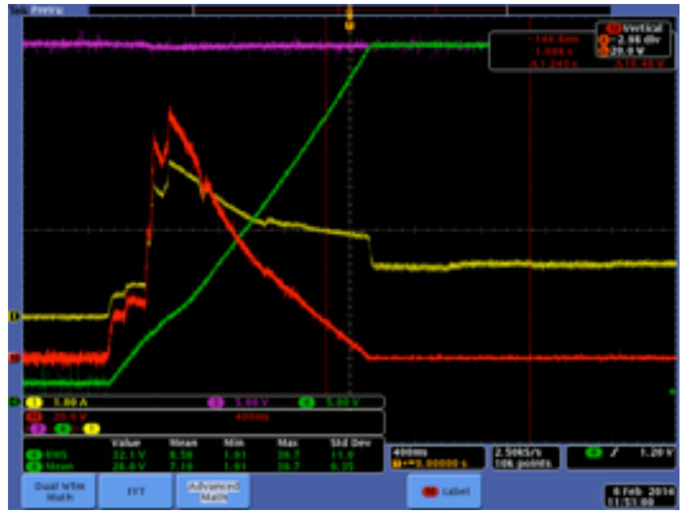


Figure 1. Start-up transients were measured and reigned in with the help of Tektronix test instrumentation.

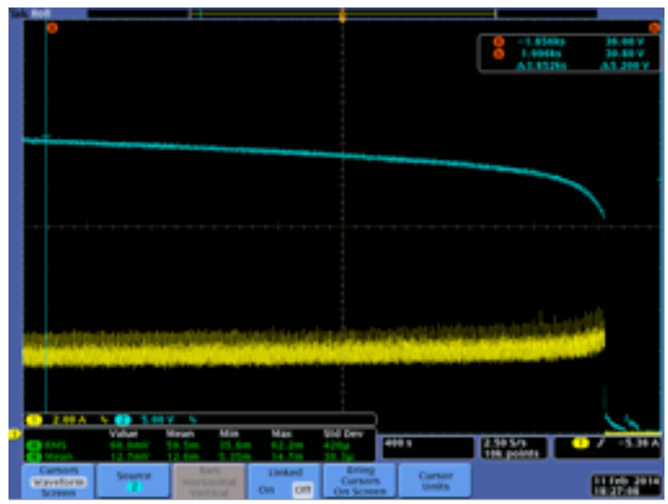


Figure 2. The MSO4104B deep memory was used to characterize battery discharge.

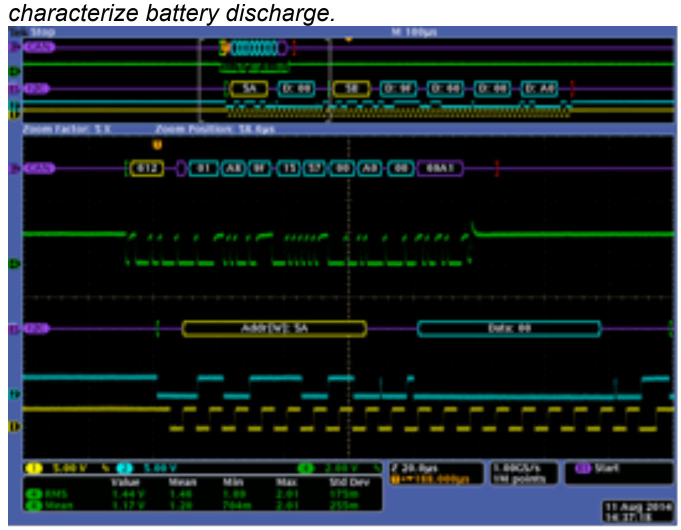


Figure 3. CAN and I2C decoding helped to speed up debug.

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